RDX in Groundwater At DoD Facilities An Overview

Ira May
US Army Environmental Center
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Scope of Problem

- **U.S. Army is presently operating major pump and treat systems at 3 installations solely for the remediation of explosive plumes.**

- **Army databases lists 20 installations where explosives in groundwater pose a potential hazard to human health and the environment.**

Scope of Problem *(Continued)*

- **Large scale (multimillion dollar) incineration , composing and soil removal programs have been undertaken to prevent further contamination of groundwater**

- **Estimated average lifetime of conventional pump and treat systems are greater than 30 years, often approaching 100 years**

DoD Operations with RDX

- **Explosive Manufacturing**
- **Demilitarization Operations**
- **Testing of new munitions**
- **Open-Burning/Open Detonation Operations**
- **Range Operations**

Installations with Explosives

Holston AAP, TN		Redstone AR, AL
Iowa AAP, IA		Milan AAP, TN
Kansas AAP, KS		Savannah AD, IL
Lone Star AAP. TX		Cornhusker AAP, NE
Radford AAP, VA		Umatilla CD, OR
Ravenna AAP, OH		Camp Navajo, AR
Aberdeen PG, MD		Dugway PG, UT
Newport CA, IN		Tooele AD, UT
Pueblo CD, CO		Volunteer AAP, TN
Picatinny Arsenal, NJ		Fort Devens, MA
Fort Wingate, NM		MMR, MA

Table 2.2
Partial List of XACs Identified in Manufacturing Waste Streams, Wastewater Lagoons, or Contaminant Plumes[1]

Compound(s)	Abbreviation	Comments
TNT-Associated Compounds		
2,4,6-trinitrotoluene	TNT or 2,4,6-TNT	Historically, most important high explosive in U.S.; widely used
2,5,6-trinitrotoluene and other isomers	2,5,6-TNT et al.	One of 6 TNT isomers; asymmetric TNT byproducts removed
2,3-, 2,4-, 2,5-, 2,6-, 3,4-, and 3,5-dinitrotoluene	2,3-DNT, ..., 3,5-DNT	Impurities in TNT; 2,4- & 2,6- isomers are most common in waste streams and low-melting mixtures
1,3,5-trinitrobenzene	TNB	Photolytic alteration of 2,4,6-TNT (oxid., decarbox.) or impurity in TNT; photolysis product
1,3-dinitrobenzene	1,3-DNB	Alteration of 2,4- or 4,6-DNT or byproduct of TNT
2-amino-4,6-dinitrotoluene, 4-amino-2,6-dinitrotoluene	2-A-4,6-DNT, 4-A-2,6-DNT	TNT nitro-to-amino reduction reaction products
2,4-diamino-6-nitrotoluene, 2,6-diamino-4-nitrotoluene	2,4-A-6-NT, 2,6-A-4-NT	Further nitro-to-amino reduction reaction products from mono-amino compounds
RDX-Associated Compounds		
Hexahydro-1,3,5-trinitro-1,3,5-triazine	RDX	Currently, the most important military high explosive in U.S.; RDX = Research Department or Royal Demolition eXplosive
Octahydro-1,3,5,7-tetra-nitro-1,3,5,7-tetrazocine	HMX	Propellant; acceptable production impurity; HMX = High Melting Explosive or Her Majesty's eXplosive
1-acetylhexahydro-3,5-dinitro-1,3,5-triazine	TAX	Impurity in RDX manufacture
1-acetylhexahydro-3,5,7-trinitro-1,3,5,7-tetra-zocine	SEX	Impurity in RDX manufacture
Miscellaneous Munitions-Associated Compounds		
N,2,4,6-tetranitro-N-methylaniline	Tetryl	Booster explosive; use largely superseded by RDX
Ammonium picrate, picric acid	AP, PA	

[1] Adapted from Rosenblatt et al. (1989) and Spanggord et al. (1982a)

Groundwater Strategy

- **Source Control the highest priority**
- **Risk reduction not plume control**
- **Produce goals and objectives for each system that can be measured.**

Groundwater Strategy *(continued)*

- **Provide mechanisms for optimization of existing systems**
- **Provide alternatives to the use of pump and treat as a presumptive remedy in contaminated aquifers**
- **Greater use of innovative technologies: reactive walls, phytoremediation, biodegradation, in-situ oxidation, Fenton's reagents, etc.**

Groundwater Strategy *(continued)*

- **Containment only of plumes exhibiting imminent risk**
- **Greater use of natural attenuation in conjunction with pump and treat systems**
- **Independent review of all high cost pump and treat systems**

Groundwater Strategy *(continued)*

- **Produce an exit strategy for all pump and treat systems. This exit strategy should be in the ROD and agreed to by all parties.**

Fate and Transport

- **Sorption**
- **Biodegradation**
- **Chemical transformation**
- **Dispersion**

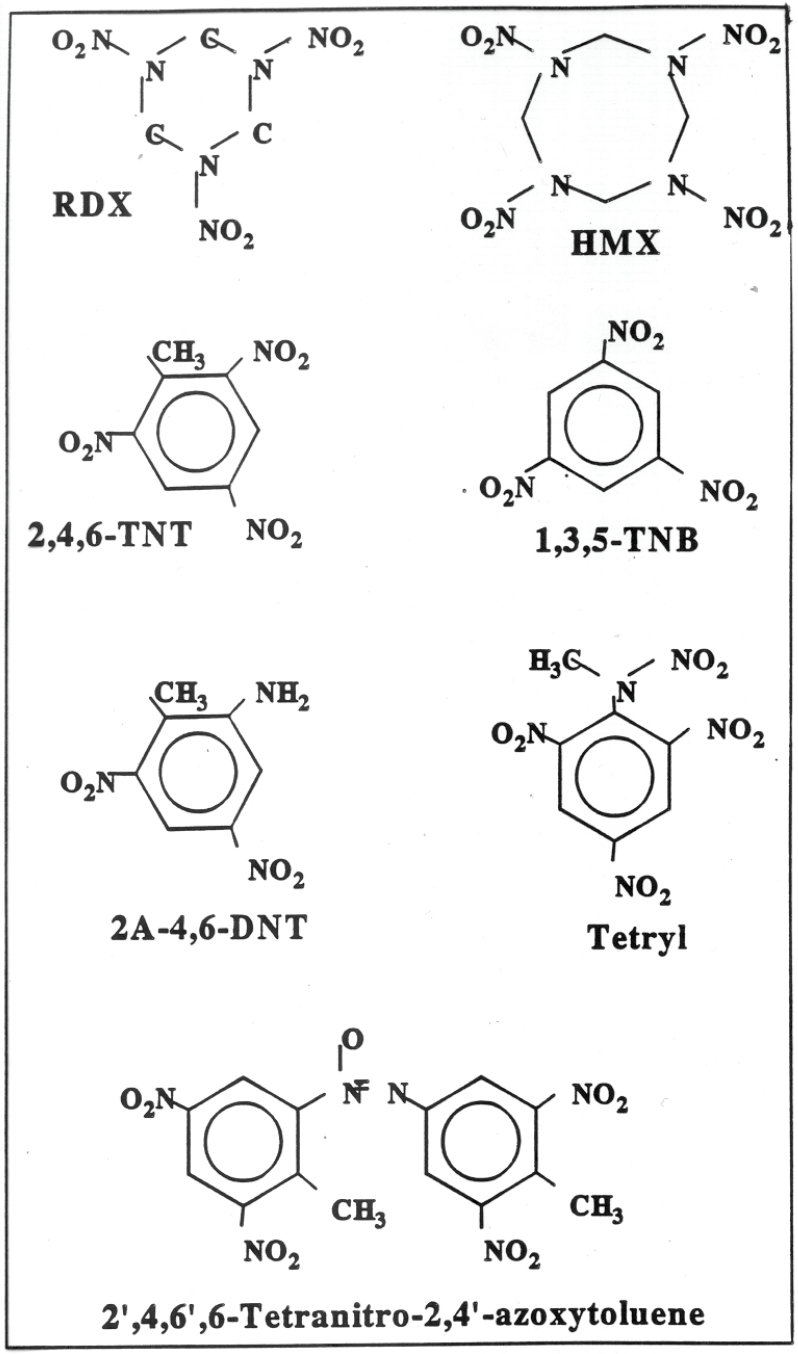


Figure 2.2. Molecular structures for a representative suite of explosives and associated compounds

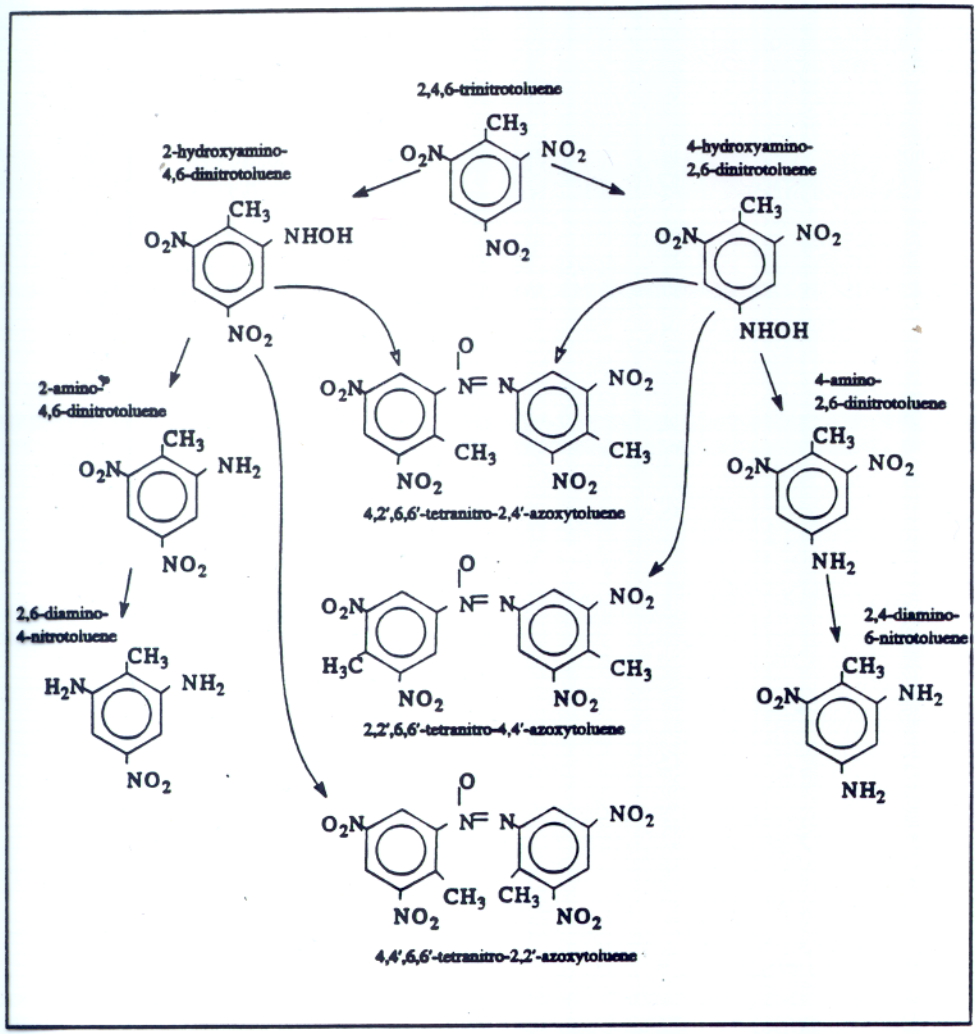


Figure 7.4. Reductive biodegradation for TNT (modified from Kaplan and Kaplan (1982) and Kaplan (1993))

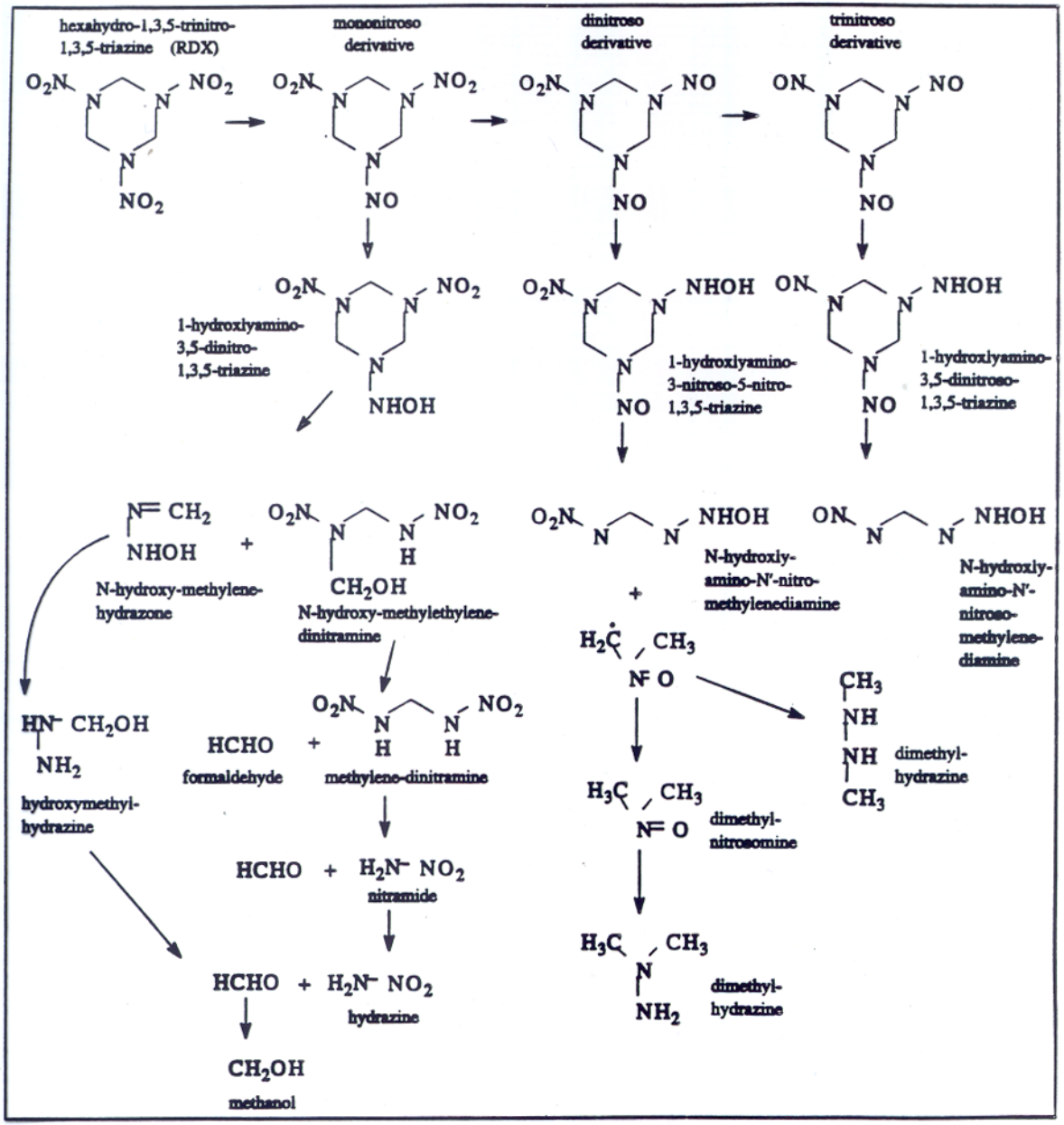
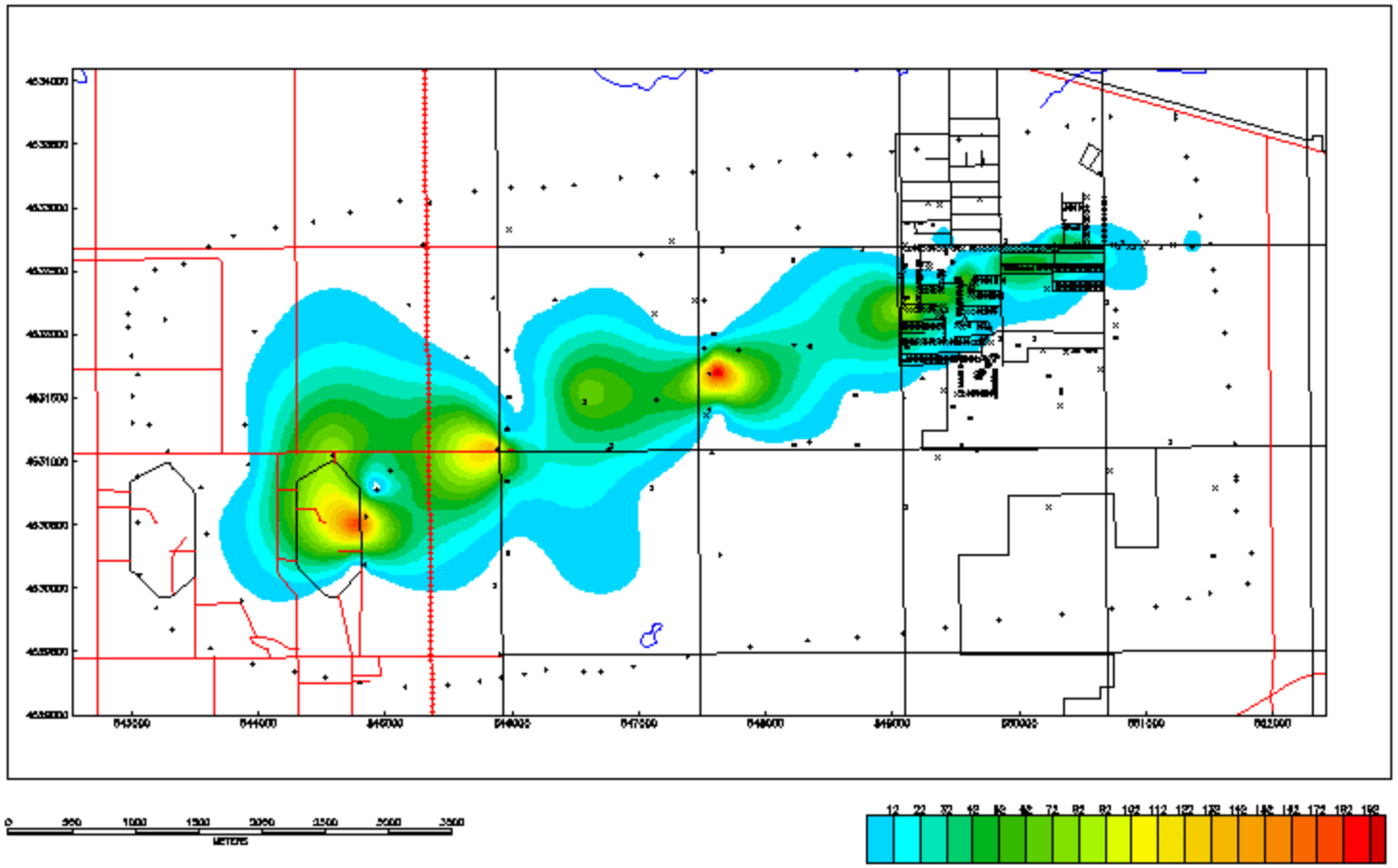
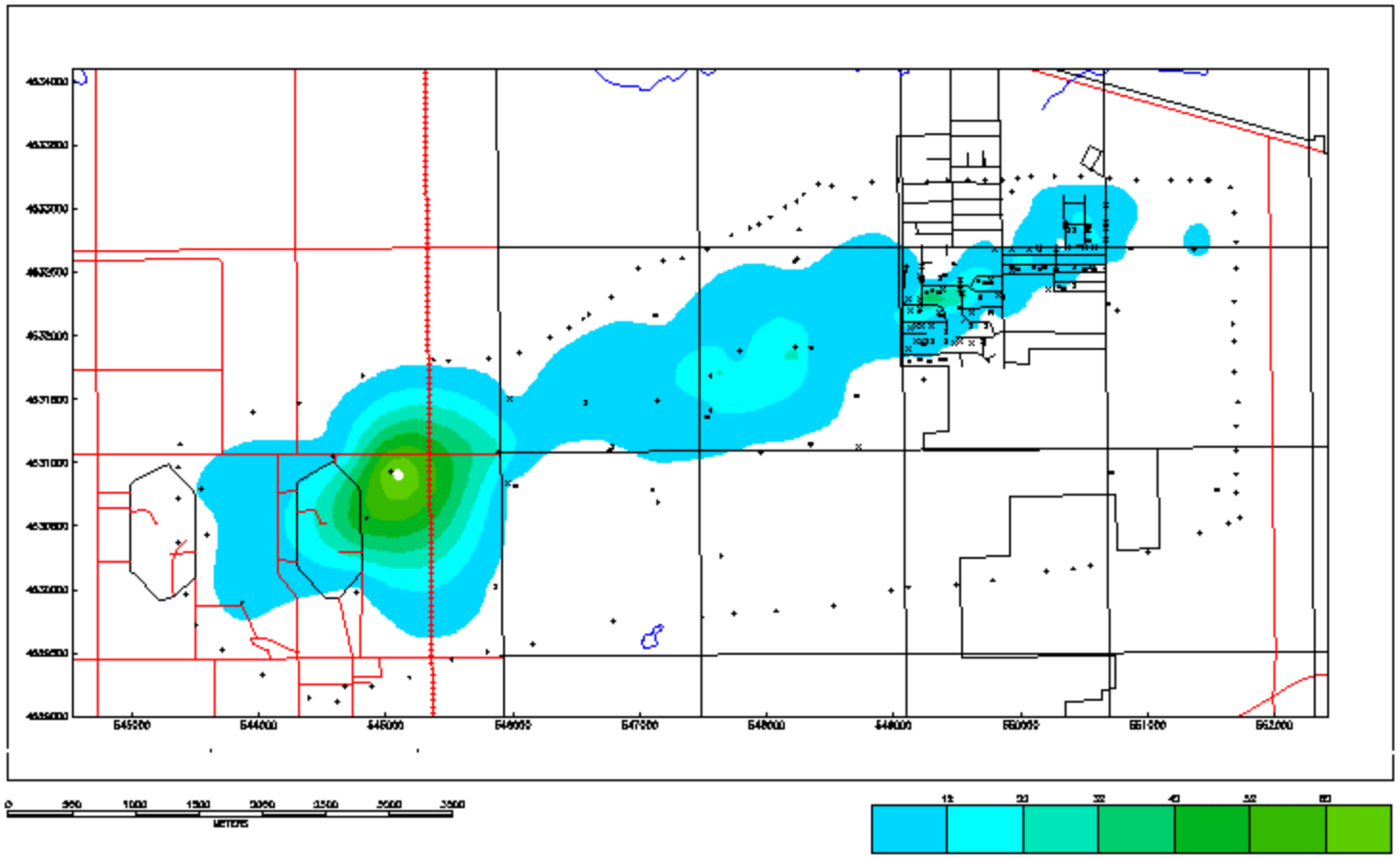


Figure 7.5. RDX anaerobic reaction pathway (after Kaplan (1993))

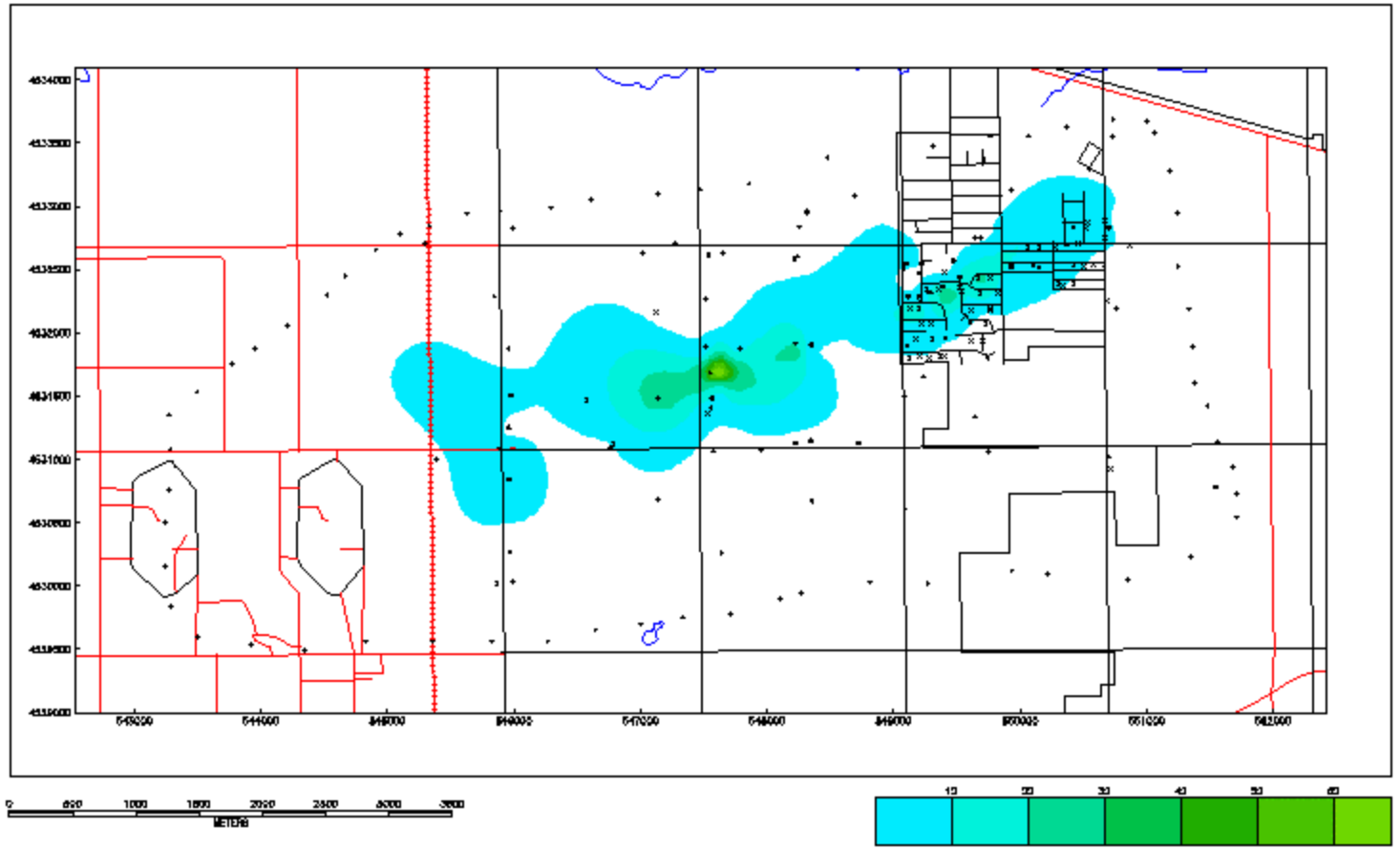
1982 Cornhusker RDX Plume



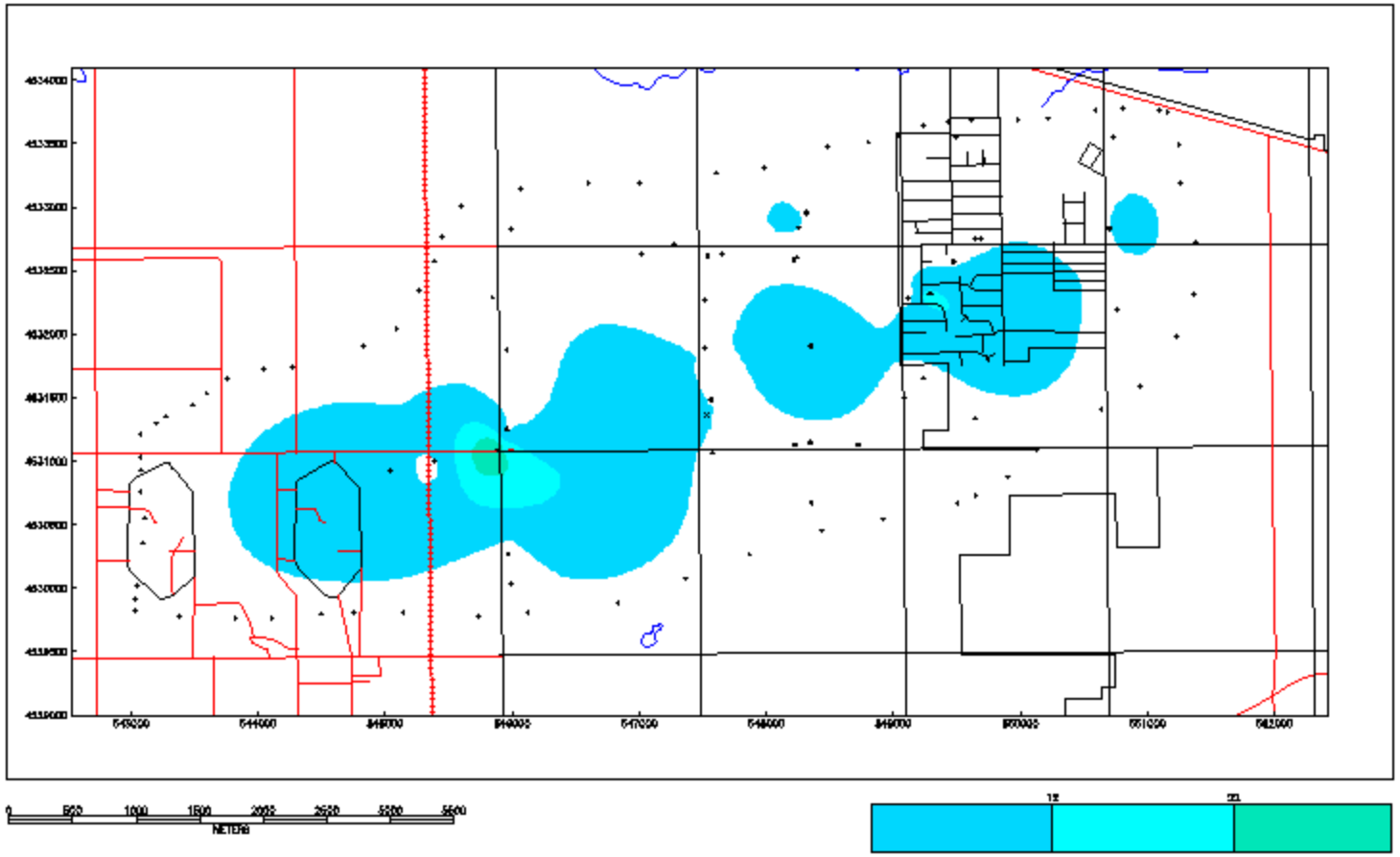
1988 Cornhusker RDX Plume



1990 Cornhusker RDX Plume



1994 Cornhusker RDX Plume



Ex-Situ Cleanup Technologies

- **Granulated Activated Carbon (GAC)**
- **Phytoremediation**
- **UV/OX**
- **Hot Gas Decontamination**

In-Situ Cleanup Technologies

- **Chemical Oxidation**
- **Enhanced Biodegradation**
- **Reactive Walls**
- **Natural Attenuation**

Important References

- McGrath, C, 1995, Review of Formulations for Processes Affecting the Subsurface Transport of Explosives, WES Technical Report IRRP-95-2

- Brannon, J,1997, Review of Fate and Transport Process of Explosives WES Technical Report IRRP-97-2

- http://www.aec.army.mil